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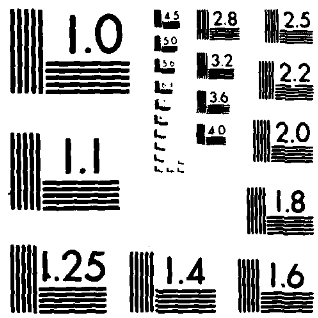

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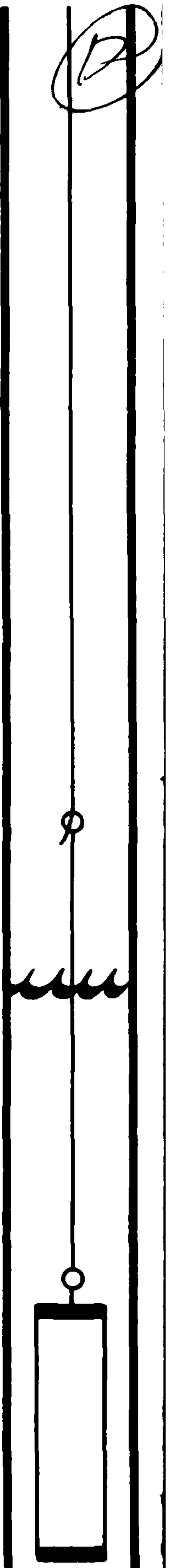

Variable Buoyancy Cannister For Ocean Applications

Introduction

Many ocean applications employing free or tethered equipment include the requirement for a variable buoyancy capability. A simple and reliable variable buoyancy cannister, suitable for many such applications, has been developed, under Office of Naval Research (ONR) support, at the Institute of Geophysics and Planetary Physics (IGPP) at Scripps Institution of Oceanography.

Design Goals

The IGPP buoyancy cannister described here was developed in support of a program of ocean measurements employing a yo-yoing midwater float to take repeated profiles of a short segment of the water column at depths to 1 km. The design goals include light weight, constant mass, minimum battery requirements, a 1000 cc volume change in less than 30 seconds, and the capability of undergoing 10 volume changes per hour for 3 months. The buoyancy cannister described meets these requirements.

System Design Description

The IGPP variable buoyancy cannister is shown in Figure 1. A key design feature to minimize mechanical and electrical requirements for the system is the use of a cannister pressurization system. Pressurizing the cannister reduces the opposing pressure head the piston must work against, and also allows use of a lightweight cannister body. The cannister is pressurized with dry nitrogen by directing the output of the first stage of a standard, single-hose scuba regulator to an 100 psi pqp-off valve venting into the cannister

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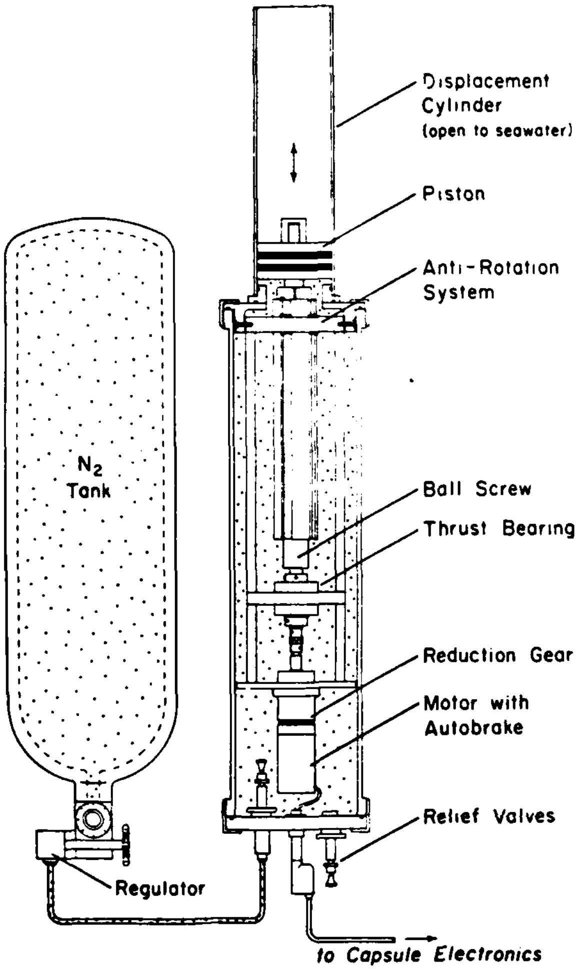

FIGURE 1.

interior. A second 100 psi pop-off valve vents to the water. This pressurization approach has the advantage that its principal element has the reliablility found only in "man-rated" equipment and is relatively inexpensive.

The volume of the IGPP variable buoyancy cannister is varied by a piston, as shown in Figure 1. The integrity of the sliding seal of the piston in the bore has received careful attention. O-rings exhibit an undesirable behavior known as "spiraling" in applications having slow sliding velocities. For the present application, therefore, we have used instead ethylene propylene "polypac seals" made by the Parker Packing Company. When this design is used in water containing appreciable quantities of particulates, a wiper, scraper, or a flaccid, fluid-filled bladder should be used to protect the cylinder bore from abrasion.

Two testing methods have been used to assure proper functioning of the piston seal. For routine, pre-cruise testing we evacuate the cannister and use a helium leak tester. Running the piston back and forth under these condidtions shows only a very small leakage detectible on the most sensitive range of the tester. For initial, post-construction testing of the cannister, we simulated an actual ocean deployment by exercising the cannister for 12,000 full-range piston strokes in a pressure vessel of seawater at 900 psi with 80 psi differential pressure. At the end of this run there was no sign of wear and only a slight film of moisture (<< 1 cc) on the inboard part of the cylinder wall.

The piston position is controlled by a gear motor turning a low friction ball-screw. An electrically released brake on the gear motor holds the piston in position against the opposing pressure head, except when the motor is running. Maximum electrical requirements for the buoyancy cannister are 1.4 Ah at 28 V per 1000 in-and-out cycles.

A toothed rubber belt (not illustrated) is attached to the piston base and is used to control the value of a variable resistor in the cannister. Two wires connect this variable resistor to a separate piston position monitoring and control circuit.

The cannister system also includes a water leak detector at each end, which allows positioning the

cannister in either a piston-end-up or piston-end-down mode. The piston head leak detector is connected by a tubular slide contact that permits full piston motion without interference.

Discussion

As the cannister descends to its operating depth (< = 1 km), the pressure regulator supplies nitrogen to the cannister interior to balance the rising ambient pressure. The buoyancy cannister is a constant mass system, provided the pressure difference between the cannister interior and the ambient ocean pressure remains in the range ± 100 psi. If the vertical excursions of the cannister take it outside of this 200 psi range, then nitrogen is, in effect, pumped from the supply tank to the cannister and then to the outside world. If this pumping action is taking place, the limit on how long the cannister can be usefully employed may be set by the mass loss, or the nitrogen supply, rather than the battery supply.

With present pop-off valve settings, the design goals for the buoyancy cannister are well met for applications in which the depth excursions of the system are less than approximately ± 65 m from the mean depth of the deployment. This range can be increased, of course, by using higher pressure settings on the pop-off valves. The resulting higher loads on the cannister motor and pressure housing must be properly taken into account.

The buoyancy cannister described has served us at sea without difficulties of any kind.

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"POPCORN"-- A Simple Answer To Wide Area Data Collection

Background Information

There are many applications for a simple wide area data collection system. Meteorological and/or navigational buoys for ocean scientists and the monitoring of a multitude of parameters for other disciplines always present a major problem to any project. The "POPCORN" system as described in this article has been applied over the past few months to a number of remote measurement problems, including: temperature, pressure, relative humidity, soil resistivity, snow pillows, precipitation, well depth, and several other parameters of interest. The system is basically simple in its design and uses existing wide area communication networks to complete the data acquisition and processing loop. The initial reason for undertaking development of this system was to provide for the remote measurement of water resource parameters within the state of Nevada.

The proper management of water resources is rapidly becoming a national problem[1]. Both water quality and quantity are significant parameters of interest. The Western States in particular have been facing periodic drought conditions. Also, many locations throughout the United States are concerned with the intrusion of surface contaminents into groundwater resources.

Water resource monitoring on a large scale requires that there be a wide area communications network available to gather the data necessary for modeling and/or subsequent management of one of this country's most valuable resources, i.e., water. Many states, for example, have been conducting well monitoring for a number of years; however, in most cases, the sampling of groundwater is accomplished by manual techniques. That is, each test well is visited and depth and/or water quality parameters are measured and subsequently recorded. This is a very time-consuming, labor-intensive, and hence an extremely expensive process. In some cases, remote sensors can be used with the data telemetered to a central location for analysis and historical recording. Such automated techniques can be quite expensive since each test well requires not only sensors but also a communications link from the test well to a central facility. This can involve the use of mountain top repeaters, satellite systems, telephone circuits and/or a combination of these. In general, the costs of such systems are prohibitive and, hence, wide area test well monitoring by automated methods is not widely used.

The U.S. Soil Conservation Service (SCS) and U.S. Geological Survey (USGS) have been conducting water resource monitoring and providing related services for many years. SCS snow survey forecasts, for example, have proven valuable to flood control and municipal water supply agencies, reservoir operations, power companies, recreation enterprises, industries, and fish and wildlife managers. For decades, snow survey data have been gathered manually. Snow surveyors had to visit high-mountain sites on skis, snowmobiles, or helicopters. Measuring snow depth and water content was more than a little dangerous in many locations.

SNOTEL, an automated data collection system, eliminates time-consuming manual data collection on the most hazardous snow courses. The system combines automatic measuring equipment and a revolutionary meteorburst communications technique. SNOTEL provides faster, more accurate data, more often, on which to base forecasts. SNOTEL is a data and communication transmission system using meteor scatter propagation with a master station, fixed remote station, portable communication units, and all necessary support items. Briefly, meteor scatter, or more commonly meteor-burst communications, relies on the electrons in meteor trails to reradiate or reflect radio waves in the low VHF frequency range for distances up to 1200 miles.

The meteor trail characteristics dictate the techniques for utilization of the media as a communications path.

Meteor-burst systems have been developed to the commercial stage; in fact, both Western Union* and Meteor Communications Corporation have developed commercially available Meteor-burst communications equipment. One of the first such systems, SNOTEL,, is currently being used by the SCS. In this system, two master stations are located so as to cover the entire Western United States. One station is located in Ogden, Utah, and the other in Boise, Idaho. There are currently some 500 remote sites located throughout the Western States covered by these two master stations. Data are forwarded by telephone lines from these two collection stations to a computer located at the SCS West Technical Service Center in Portland, Oregon.

Snow survey supervisors in the Western States are now able to obtain minutes-old information from the computer via terminals located in the SCS state office. States included in the SNOTEL network are Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Although a number of remote sites in Alaska are being automated they will not be tied into the network. In California, SCS is working with the State Department of Water Resources which has its own survey and forecasting program. Automated SNOTEL sites go into operation as they are linked to the new communication system.

The USGS has been applying another advanced remote data gathering system using the Geostationary Operational Environmental Satellite system (GOES). The GOES satellite data collection system (DCS)[4], is telemetric and uses an Earth-orbiting satellite to relay data from hundreds or thousands of widely distributed environmental sensors to one or more data receiving stations. There are three basic elements of any DCS. The first element is a field radio, usually called a data collection platform (DCP), that is connected to environmental sensors such as precipitation or water-level recorders. The second element is a radio transponder (receiver/transmitter) on an Earth-orbiting satellite that is capable of receiving messages from a large number of DCP's. The third element is the data receiving station where data are retrieved from the satellites, processed, and disseminated to users. A satellite DCS can be configured in numerous ways that affect the cost, versatility, and ease of operation of the total system. The basic problem with using networks such as the GOES and meteor-burst systems is the cost of the remote stations as well as the maintenance and operating costs.

Scientific Engineering Instruments, Inc. (SEI), in cooperation with local governments and the University of Nevada, Reno, conducted a survey of existing technology for water resource monitoring. A subsequent report recommended a remote system based on meteor-burst communications and/or GOES. It was made quite clear in the SEI report[1], that a significant breakthrough in remote monitoring technology was indeed possible.

The basis of this concept uses an innovative solution to the wide area monitoring problem called the Sub-Telemetry System (STS). An integral part of this overall system also requires that continuing research efforts be directed into methods for having the data collected, processed, displayed, recorded, and finally disseminated to interested statewide users. The long term impact and significance that such a network can have on water resource management and control is evident. Accurate, timely information thus gathered can be directly supplied to statewide as well as local planning groups for appropriate modeling and/or historical recording. A key factor to the success of the STS was the development of the STS "POPCORN" system combined with a "piggyback" concept using existing and/or planned data collection networks such as the SNOTEL or GOES systems.

System Concepts

The STS system concept is shown in Figure 1. The DCP is either a GOES or standard meteor-burst site. The SEI system has a receive-only unit (STS-R) located adjacent to the DCP. This receiver is so placed that it looks over many other data points of interest. Each desired data point uses an STS-TX remote transmitter. These remote transmitters are of a "throw away" nature, i.e., small, low power, low cost, etc. These transmitters are programmed to transmit on a random interval, that is, no receiver or special clock is needed to self-time them. This means that one DCP site can cover an entire basin for measurements such as well depth, etc. (see Figure 1). Assume that the one DCP overlooks some thirty test wells located in a basin of interest. Each well would have a depth or quality sensor (or any other parameter of interest). Each well would also have

* It has just been learned that Rockwell International has acquired all interests in Meteor-burst from Western Union.

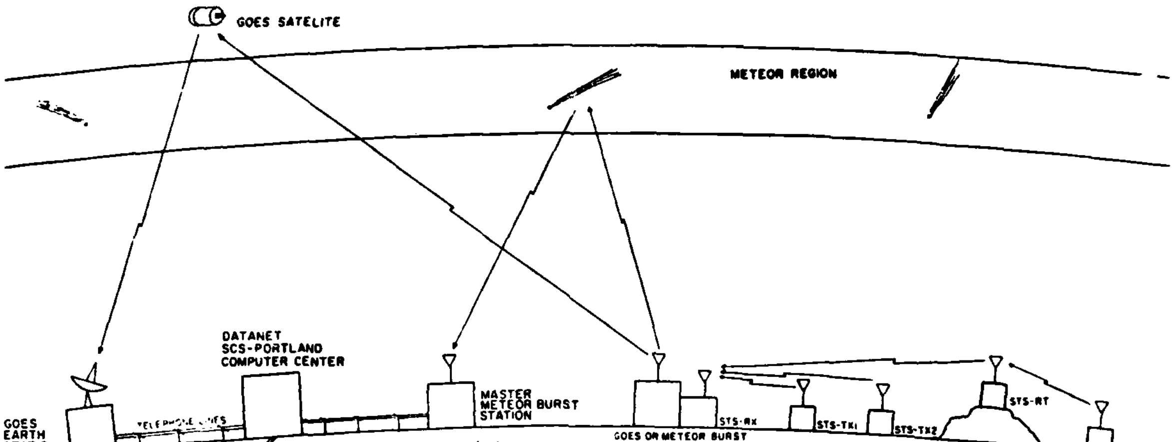

Figure (1)
BLOCK DIAGRAM OF WIDE AREA
COMPUTERIZED DATA COLLECTION SYSTEM

FIGURE 1. Block diagram of wide area computerized data collection system.

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a STS transmitter. It is possible to calculate the data recovery from these thirty sites using the following equation[5,6]

$$P_s = 1 - (1 - e^{-2tM/T})^n$$

where

P_s is the probability of successfully receiving a transmission in a given time,

n is the number of transmission tries in the observation time,

t is the length of each transmission,

T is the time interval between transmissions, and

M is the number of transmitters operating in the channel of interest.

For example, further assume that the transmissions from each site consist of a 4-second data burst at a random interval of average value 10 minutes then, in any given hour, the probability of data recovery at the DCP (STS-R) site would be given as:

$n = 6$ transmissions/site/hour

$t = 4$ seconds/site

$$T = \frac{3600}{n} = \frac{3600}{6} = 600 \text{ seconds}$$

$M = 30$ sites

then

$$P_s = 1 - \left\{1 - \frac{e^{-2}(4)\ (30)}{600}\right\}^6$$

$$= 1 - (0.0013) = 0.9987$$

This means that there would be a data recovery (in 1 hour) of 99.9 percent of the 30 sites reporting. This is quite interesting since all 30 transmitters can operate in a random transmit mode and do not require receivers or expensive self-timed clocks to trigger them.

The next innovative concept used by SEI is the use of the existing meteor-burst frequency. Since the meteor-burst system is already licensed throughout the Western States, the addition of these sub-sites is easily covered under the existing FCC license and, hence, little time is lost applying and/or obtaining the many sub-site licenses. The STS is now operational at several SNOTEL sites in Nevada, Washington, and California.*

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* SEI units have also been helicopter-lifted into the volcano crater at Mt. St. Helens to monitor snow levels for mud slide information.

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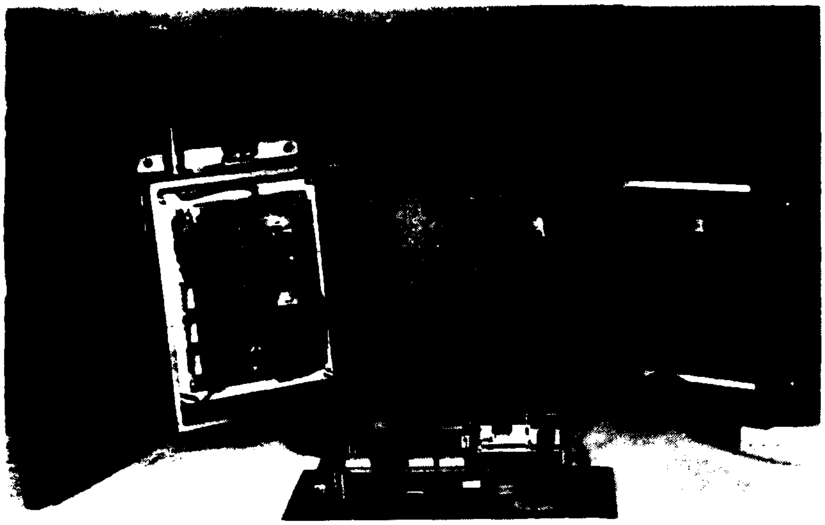

FIGURE 2.

Photograph showing the "POPCORN" subsystems:

(a) Repeater STS-RT

(b) Receiver STS-RX

(c) Transmitter STS-TX

Testing of a GOES is also being planned in Western Nevada with the cooperation of the USGS and the Desert Research Institute (DRI) of the University of Nevada. Parameters of interest for this program include well depth and the remote measurement of various soil parameters including temperature, moisture, etc.

Brief Technical Description of the STS

The standard STS-TX remote transmitter unit consists of an 8-channel data acquisition system connected to a microcomputer and associated control electronics. The unit has an internal rechargeable battery pack so that solar panels and/or any other recharging method may be used for sustained operations. The system transmits on a random basis with each transmisssion being less than 1 second in length. The system automatically shuts down between transmissions in order to conserve energy. The STS-TX also provides power (if needed) to an interface and/or sensor package. The internal battery pack allows for at least 60 days of operation without recharge for a transmission interval of average value 10 minutes. The FM transmitter provides an output of 1.5 watts using subcarrier frequency shift modulation (FSK) for the data. A standard interface box can also be provided for connection to any SNOTEL system.

The STS-RX receiver system was designed around a microcomputer providing for maximum flexibility to the user. In the case of a SNOTEL system, the STS-R unit is connector-compatible with a standard SNOTEL transceiver system. The STS-RT repeater system is used where "line-of-sight" radio paths do not exist between the "POPCORN" transmitters and the central receiver. The receiver and transmitter antennas are selected according to local requirements and can be a simple "whip" or any other type of vertically polarized antenna. The STS system can also be programmed to operate on a random adaptive basis. This means that the data reporting cycle can be adjusted by program changes, which provide intensive sampling only when it is required[6]. The three major subsystems are shown in Figure 2.

The entire system is packaged into a small NEMA-type four enclosure (H = 10", W = 8", D = 4").

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